ORIGINAL ARTICLE

Seasonality of Poor Pregnancy Outcomes in North Carolina

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BACKGROUND Seasonal variation in poor pregnancy outcomes has not received the same level of research attention and rigor as has the well-established seasonal variation in births.

METHODS In this analysis of data from the 2001-2005 North Carolina Detailed Birth Record, we use season of conception as a proxy for environmental or other risk factors. We model the continuous pregnancy outcome of birth weight percentile for gestational age by use of linear regression. We use logistic regression to model the binary pregnancy outcomes of low birth weight (<2500 g), preterm birth (<37 weeks), and small for gestational age (<10th percentile of birth weight for gestational age).

RESULTS We found significant seasonal patterns in poor pregnancy outcomes. Our results suggest that, in North Carolina, seasonal patterns are most pronounced among non-Hispanic white women living in urban areas.

LIMITATIONS The present study is limited by the restricted set of maternal and pregnancy variables available in this data set. Richer data, potentially including psychosocial and activity measures of the women, would allow us to more ably discern what is driving the seasonal patterns we observed. The pronounced increased risk associated with a spring season of conception provides an important clue for determining the true causative factors.

CONCLUSIONS Poor pregnancy outcomes in North Carolina follow a clear seasonal pattern based on timing of conception, with patterns most pronounced among non-Hispanic white women living in urban areas. These seasonal patterns are suggestive of causative environmental factors and certainly warrant additional research.

Seasonal variation in births is well-established [1, 2]. For example, in the United States, the annual pattern of birth has been characterized by a peak during August and September, with a trough in early spring [1]. Correspondingly, conceptions increase from October to January [2]. Timing of conception is suggestive of periconceptional maternal environmental risk factors that may impact pregnancy health, and it may also predispose a pregnancy to a particular set of seasonally varying exposures during specific gestational windows of vulnerability, which may be harmful to maternal and fetal health. The season or month of conception has been associated with early pregnancy loss [3], small for gestational age [4], preterm birth [4], pregnancy-induced hypertension and preeclampsia [5, 6], and birth defects [7-9]. Studies have also demonstrated a relationship between birth month or season and various pregnancy outcomes [4-6, 10].

The factors underlying the association between conception or delivery timing and pregnancy outcomes are unclear [1, 3]. It has been hypothesized that seasonal variation in pregnancy outcomes is related to seasonally varying environmental exposures possibly connected to agricultural activity [3, 7, 9], air pollution [10], biologic processes induced by climatic changes [6], alterations in circadian rhythm (affecting vitamin D intake) [6], and changes in outdoor ambient temperature (influencing total energy intake, infection, and physical activity) [11]. In addition, in developing countries, differences in the availability of food items during the year [8] and seasonal patterns in endemic diseases (eg, malaria) [12] have also been emphasized.

Understanding why the timing of conception or delivery matters to maternal and fetal health is especially important in the context of identifying causes of racial disparities in pregnancy outcomes between black women and white women in the United States. Season of conception and delivery have been shown to vary by geography [13, 14], culture [14], and maternal sociodemographic characteristics [1, 15, 16]. For example, in an Atlanta, Georgia–based study, while the birth rate peaked during spring months (summer conceptions) for college-educated women, less-educated groups experienced a trough in births during the same months—the largest of which was observed among non-Hispanic black women and Hispanic women who were unmarried and had less than a high school education [1]. Thus, the timing of conception or delivery, as well as pregnancy outcomes, may depend on sociocultural or geographic characteristics, which would, in turn, affect the exposures to seasonally varying environmental risk factors experienced by different subpopulations.

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In the present study, we use season of conception as a proxy for environmental exposures that are harmful to maternal and fetal health and that may differ on the basis of maternal race and place of residence. We select season of conception over season of birth because season of conception represents an anchor from which to assess the potential impact of seasonality (ie, 2 women who conceive in mid-February will have the same season of conception, but their season of birth may differ, depending on the gestational age at which their babies are born). We place an additional focus on race because of the pronounced disparities in pregnancy outcomes between non-Hispanic black women and non-Hispanic white women in the United States, especially in the American South [17-19]. Using North Carolina statewide data on pregnancy outcomes, we examine (1) whether season of conception is associated with birth weight and gestational age, (2) whether this association differs between black and white women, and (3) whether this association differs between women residing in an urban area and women residing in a rural area.

Methods

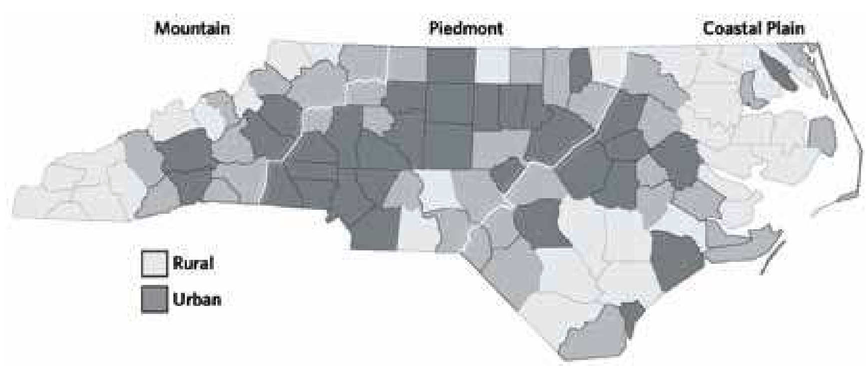
Data. The North Carolina Detailed Birth Record (NCDBR) provides data on all documented live births that occur in the state of North Carolina [20], including information on maternal demographic characteristics, maternal and infant health, and maternal obstetrics history. In validation studies across the United States, including in North Carolina, administrative birth certificate data have been shown to be accurate, particularly for demographic and birth outcome variables [21-24]. For this analysis, we restricted the data set to singleton first births to non-Hispanic white women and non-Hispanic black women, with an estimated date of conception during 2001-2005 (n = 197,535). We excluded births with missing covariate data (n = 358), congenital anomalies (n = 1660), birth weight <400 g (n = 258), and extremely high or extremely low gestational age (<24 weeks or >42 weeks; n = 5985) or maternal age (<15 years or >44 years; n = 998). With these restrictions, 188,276 births qualified for inclusion. All work was performed in compliance with a research protocol approved by Duke University's institutional review board.

Gestational age was calculated as the difference in completed weeks between the date of birth and the date of last normal menses. We used an algorithm provided by the North Carolina State Center for Health Statistics (M. Avery, personal communication); if the calculated gestational age was not reasonable on the basis of the birth weight, the clinical estimate of gestation was used, instead of the calculated gestational age. By use of the algorithm provided by the North Carolina State Center for Health Statistics, 1.3% of births were assigned the clinical estimate of gestation, instead of the calculated estimate of gestation. The date of conception was calculated as 2 weeks less than the difference between the date of birth and the gestational age [5, 25]. Season of conception was then assigned on the basis of the month of conception, with winter defined as December-February, spring as March-May, summer as June-August, and fall as September-November.

Since the type and level of environmental exposures are likely to vary by geography and urbanization, we assigned a region of North Carolina and a level of urbanization to all births, on the basis of the county of residence. Three geographic regions of North Carolina—the coastal plain, in the east; the piedmont, in the center; and the mountains, in the west—are well-established. We used county-level population density, on the basis of 2000 US Census data, to classify the 100 counties in North Carolina into 3 levels of urbanization. The 33 counties with the highest population density were classified as "urban," the 33 counties with the lowest population density were classified as "rural," and the remaining 34 counties were classified as "suburban" (Figure 1).

Statistical analysis. We modeled the continuous pregnancy outcome of birth weight percentile for gestational age by use of linear regression. Logistic regression was used to

FIGURE 1.
Urban and rural counties in North Carolina, defined as the 33 counties with the highest and the lowest population densities, respectively, in 2000



model the binary pregnancy outcomes of low birth weight (<2500 g), preterm birth (<37 weeks), and small for gestational age (<10th percentile of birth weight for gestational age). Although a race-specific definition of low birth weight might be more appropriate, we applied the widely used definition of low birth weight as <2500 g for both non-Hispanic white and non-Hispanic black births, to maintain comparability with previous literature. In addition to controlling for season of conception, all models controlled for maternal age, maternal education, maternal marital status, maternal tobacco use during pregnancy, infant sex, and region of North Carolina (ie, coastal plain, piedmont, or mountains). Since both very young maternal age and very old maternal age are associated with adverse pregnancy outcomes, we categorized maternal age into 5-year age groups: 15-19, 20-24, 25-29, 30-34, 35-39, and 40-44 years [18]. For those models using data on all North Carolina births, the 3-level measure of county urbanization was included as a covariate. All statistical analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC).

Since the work in the present study is designed as an exploratory tool for generating hypotheses about environmental exposures that may be appropriate for further research, we fit race-specific models that use statewide birth data, as well as fitting race-specific models that focus separately on births to residents of urban and rural counties. We recognize that this approach, which requires 6 models per outcome, is somewhat cumbersome. However, it does not constrain the coefficients on the suite of explanatory variables to be constant across race or degree of urbanization. In results not shown here, we found that, for non-Hispanic black women and non-Hispanic white women, the coefficients were quite different for variables such as maternal age, maternal education, smoking status, and geographic area; thus, dealing with race-based differences by use of an interaction term would have required us to interact race with multiple covariates other than season. The multiple interactions greatly hamper ease of interpretation. In addition, if there are seasonally varying environmental exposures for which season of conception acts as a proxy for the exposures' impact on birth outcomes, we would anticipate that these exposures would be quite different between urban and rural settings (eg, pesticides may be a key exposure in rural, agricultural areas, whereas summer ozone levels may be a key exposure in high-traffic, urban areas). Given the exploratory nature of this work, we believe the benefits and flex-

TABLE 1.
Maternal Characteristics of Births, by Race and Season of Conception

Characteristic	Non-Hispanic white				Non-Hispanic black			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Age, years								
15-19	5695 (16.0)	5700 (16.9)	5419 (15.6)	5560 (15.7)	4452 (35.4)	4646 (36.7)	4310 (36.8)	4202 (35.2)
20-24	9898 (27.8)	9199 (27.3)	9118 (26.2)	9657 (27.3)	4538 (36.1)	4472 (35.3)	4023 (34.3)	4286 (35.9)
25-29	10,014 (28.2)	9271 (27.5)	9948 (28.6)	10,030 (28.4)	1894 (15.1)	1922 (15.2)	1843 (15.7)	1828 (15.3)
30-34	7171 (20.2)	6894 (20.4)	7394 (21.3)	7201 (20.4)	1142 (9.1)	1052 (8.3)	1030 (8.8)	1050 (8.8)
35-39	2408 (6.8)	2264 (6.7)	2470 (7.1)	2470 (7.0)	438 (3.5)	470 (3.7)	410 (3.5)	465 (3.9)
40-44	381 (1.1)	424 (1.3)	405 (1.2)	407 (1.2)	101 (0.8)	103 (0.8)	96 (0.8)	105 (0.9)
Educational attainment								
<9th grade	526 (1.5)	465 (1.4)	477 (1.4)	466 (1.3)	236 (1.9)	263 (2.1)	280 (2.4)	249 (2.1)
Some high school	3910 (11.0)	3871 (11.5)	3724 (10.7)	3844 (10.9)	2843 (22.6)	3140 (24.8)	2871 (24.5)	2612 (21.9)
Completed high school	9488 (26.7)	8962 (26.6)	8751 (25.2)	9122 (25.8)	4502 (35.8)	4296 (33.9)	4029 (34.4)	4208 (35.3)
Some college	8483 (23.9)	7900 (23.4)	7931 (22.8)	8358 (23.7)	2897 (23.1)	2947 (23.3)	2532 (21.6)	2804 (23.5)
Completed college	13,160 (37.0)	12,554 (37.2)	13,871 (39.9)	13,535 (38.3)	2087 (16.6)	2019 (15.9)	2000 (17.1)	2063 (17.3)
Not married	9984 (28.1)	9625 (28.5)	9370 (27.0)	9837 (27.8)	9674 (77.0)	9943 (78.5)	8957 (76.5)	9171 (76.8)
Smoked during pregnancy	5107 (14.4)	4719 (14.0)	4546 (13.1)	4695 (13.3)	865 (6.9)	823 (6.5)	728 (6.2)	735 (6.2)
Region of NC								
Coastal Plain	10,021 (28.2)	9266 (27.5)	9467 (27.2)	9979 (28.2)	4839 (38.5)	4912 (38.8)	4353 (37.2)	4563 (38.2)
Piedmont	20,743 (58.3)	19,741 (58.5)	20,463 (58.9)	20,513 (58.1)	7398 (58.9)	7451 (58.8)	7056 (60.2)	7078 (59.3)
Mountains	4803 (13.5)	4745 (14.1)	4824 (13.9)	4833 (13.7)	328 (2.6)	302 (2.4)	303 (2.6)	295 (2.5)
County urbanization								
Rural	2379 (6.7)	2347 (7.0)	2394 (6.9)	2419 (6.8)	1069 (8.5)	1064 (8.4)	957 (8.2)	981 (8.2)
Suburban	6834 (19.2)	6492 (19.2)	6334 (18.2)	6727 (19.0)	1990 (15.8)	2039 (16.1)	1787 (15.3)	1811 (15.2)
Urban	26,354 (74.1)	24,913 (73.8)	26,026 (74.9)	26,179 (74.1)	9506 (75.7)	9562 (75.5)	8968 (76.6)	9144 (76.6)
Total	35,567	33,752	34,754	35,325	12,565	12,665	11,712	11,936

Note. Data are no. (%). Winter, December-February; spring, March-May; summer, June-August; fall, September-November. NC, North Carolina.

TABLE 2.
Pregnancy Outcomes, by Season of Conception and Race

	Non-Hispanic white				Non-Hispanic black			
Outcome	Winter (n = 35,567)	Spring (n = 33,752)	Summer (n = 34,754)	Fall (n = 35,325)	Winter (n =12,565)	Spring (n =12,665)	Summer (n =11,712)	Fall (n =11,936)
Birth weight percentile for gestational age, mean (SD)	48.6 (28.4)	48.3 (28.5)	49.1 (28.3)	48.8 (28.4)	36.6 (27.1)	36.9 (27.1)	37.5 (27.2)	36.8 (27.3)
LBW	6.8%	7.3%	6.7%	6.6%	13.1%	13.2%	13.1%	13.0%
PTB	9.7%	10.6%	10.2%	9.6%	14.0%	14.8%	15.6%	14.8%
SGA	10.0%	10.3%	9.5%	9.8%	18.9%	18.7%	18.3%	19.3%

Note. Winter, December-February; spring, March-May; summer, June-August; fall, September-November. LBW, low birth weight (<2500 g); PTB, preterm birth (<37 weeks); SD, standard deviation; SGA, small for gestational age (<10th percentile of birth weight for gestational age).

ibility of fitting both regionally and racially stratified models outweigh the risk of type I error associated with the additional models.

Results

Table 1 presents the maternal characteristics of births by race and by season of conception. Clear differences in maternal characteristics exist between non-Hispanic white births and non-Hispanic black births; however, for both race groups, although there was some variation by season of conception, there were no dramatic differences in the distribution of maternal characteristics across seasons. This finding differs from the findings of some analyses of national data [1, 16]. The composition of births, in terms of geographic region and level of urbanization, was also fairly constant across seasons. The breakdown of births by geographic region and level of urbanization is consistent with the proportion of the overall population residing in each region and in counties classified by level of urbanization. There appeared to be more seasonal variability in maternal characteristics among births to residents of rural counties, compared with trends found in the statewide sample. However, this may be caused by fewer observations in rural areas.

Table 2 presents pregnancy outcomes by season of conception and by race, for births in all North Carolina counties. There are clear racial disparities in birth outcomes, with non-Hispanic black births having higher rates of all adverse outcomes, compared with non-Hispanic white births. Although outcomes by urban and rural status are not included in the table, it is worth noting that the rates of adverse pregnancy outcomes in rural counties were consistently higher than those in urban counties (eg, 13.4% of births in rural counties were preterm, compared with 10.9% of births in urban counties). Spring and winter conceptions had a lower mean birth weight percentile for gestational age among statewide births for both race groups ($P < .05$), as well as among rural county births for the non-Hispanic white group ($P < .05$). Rates of small for gestational age were lowest among non-Hispanic

TABLE 3.
Covariate-Adjusted Odds Ratios (aORs) and 95% Confidence Intervals (CIs) for Binary Pregnancy Outcomes among Non-Hispanic White Births, for All Pairs of Seasons of Conception

Outcome, area	Fall vs spring	Fall vs summer	Fall vs winter	Spring vs summer	Spring vs winter	Summer vs winter
LBW						
NC	0.90[a] (0.85-0.96)	0.97 (0.91-1.03)	0.97 (0.91-1.03)	1.08[a] (1.01-1.14)	1.07[a] (1.01-1.14)	1.00 (0.94-1.06)
Rural	0.97 (0.79-1.20)	1.27 (1.02-1.59)	1.04 (0.84-1.28)	1.31 (1.05-1.63)	1.06 (0.86-1.31)	0.81 (0.65-1.02)
Urban	0.88[a] (0.82-0.95)	0.93[a] (0.87-1.00)	0.97 (0.90-1.04)	1.05 (0.98-1.13)	1.10[a] (1.02-1.18)	1.04 (0.97-1.12)
PTB						
NC	0.91[a] (0.86-0.96)	0.94[a] (0.90-0.99)	1.00 (0.95-1.05)	1.04 (0.99-1.09)	1.10[a] (1.05-1.16)	1.06[a] (1.01-1.12)
Rural	0.97 (0.81-1.15)	1.03 (0.87-1.23)	1.11 (0.93-1.33)	1.07 (0.90-1.27)	1.15 (0.97-1.37)	1.08 (0.90-1.29)
Urban	0.90[a] (0.85-0.96)	0.93[a] (0.87-0.98)	0.99 (0.93-1.05)	1.03 (0.97-1.09)	1.10[a] (1.04-1.16)	1.07[a] (1.01-1.13)
SGA						
NC	0.96 (0.91-1.01)	1.03 (0.98-1.08)	1.00 (0.95-1.05)	1.07 (1.02-1.13)	1.04 (0.99-1.10)	0.97 (0.92-1.02)
Rural	1.10 (0.92-1.32)	1.30 (1.08-1.57)	1.11 (0.93-1.33)	1.18 (0.98-1.43)	1.01 (0.84-1.21)	0.85 (0.71-1.03)
Urban	0.93 (0.88-0.99)	1.00 (0.94-1.06)	0.99 (0.93-1.05)	1.08 (1.01-1.14)	1.06 (1.00-1.12)	0.99 (0.93-1.05)

Note. Data are aOR (95% CI). Winter, December-February; spring, March-May; summer, June-August; fall, September-November. Models for each outcome were controlled for age, education, marital status, smoking during pregnancy, infant sex, and region of North Carolina (NC). Models for all NC counties also controlled for urban and rural county classification. LBW, low birth weight (<2500 g); PTB, preterm birth (<37 weeks); SGA, small for gestational age (<10th percentile of birth weight for gestational age).
[a]Indicates aOR is significant at .05 and season of conception is a significant covariate in the model, on the basis of the type III P value.

TABLE 4.
Covariate-Adjusted Odds Ratios (aORs) and 95% Confidence Intervals (CIs) for Binary Pregnancy Outcomes among Non-Hispanic Black Births, for All Pairs of Seasons of Conception

Outcome, area	Fall vs spring	Fall vs summer	Fall vs winter	Spring vs summer	Spring vs winter	Summer vs winter
LBW						
NC	1.00 (0.93-1.07)	0.99 (0.92-1.07)	1.00 (0.93-1.08)	1.00 (0.93-1.08)	1.00 (0.93-1.08)	1.01 (0.93-1.08)
Rural	1.05 (0.82-1.35)	0.96 (0.75-1.24)	1.14 (0.89-1.47)	0.91 (0.71-1.17)	1.08 (0.84-1.39)	1.19 (0.92-1.53)
Urban	0.99 (0.91-1.08)	0.98 (0.90-1.07)	0.96 (0.88-1.05)	0.99 (0.91-1.08)	0.97 (0.89-1.05)	0.98 (0.90-1.06)
PTB						
NC	1.01 (0.94-1.08)	0.94 (0.88-1.01)	1.07 (0.99-1.15)	0.94 (0.87-1.01)	1.06 (0.99-1.14)	1.13[a] (1.05-1.21)
Rural	0.91 (0.72-1.14)	0.85 (0.67-1.07)	1.13 (0.89-1.45)	0.94 (0.75-1.18)	1.25 (0.99-1.58)	1.34 (1.06-1.70)
Urban	1.02 (0.94-1.10)	0.96 (0.89-1.04)	1.05 (0.96-1.14)	0.95 (0.87-1.03)	1.03 (0.95-1.12)	1.09 (1.00-1.18)
SGA						
NC	1.05 (0.98-1.11)	1.07 (1.00-1.14)	1.03 (0.97-1.10)	1.02 (0.96-1.09)	0.99 (0.93-1.05)	0.97 (0.91-1.03)
Rural	1.04 (0.84-1.29)	0.94 (0.76-1.18)	0.93 (0.75-1.15)	0.91 (0.73-1.13)	0.89 (0.72-1.10)	0.98 (0.79-1.22)
Urban	1.03 (0.96-1.11)	1.10 (1.02-1.18)	1.05 (0.98-1.13)	1.06 (0.99-1.14)	1.02 (0.95-1.10)	0.96 (0.89-1.03)

Note. Data are aOR (95% CI). Winter, December-February; spring, March-May; summer, June-August; fall, September-November. Models for each outcome were controlled for age, education, marital status, smoking during pregnancy, infant sex, and region of North Carolina (NC). Models for all NC counties also controlled for urban and rural county classification. LBW, low birth weight (<2500 g); PTB, preterm birth (<37 weeks); SGA, small for gestational age (<10th percentile of birth weight for gestational age).
[a]Indicates aOR is significant at .05 and season of conception is a significant covariate in the model, on the basis of the type III *P* value.

white spring conceptions across all North Carolina counties, in urban counties, and in rural counties ($P < .05$). Spring conceptions also had the highest rates of preterm birth and low birth weight among non-Hispanic white births across North Carolina ($P < .05$), in rural counties ($P < .05$, for low birth weight only), and in urban counties ($P < .05$). Among non-Hispanic black births, however, summer conceptions had the highest rate of preterm birth across all North Carolina counties ($P < .05$), as well as in rural and urban counties.

To better understand the association between pregnancy outcomes and season of conception, we fit models that controlled for relevant maternal and infant covariates, as well as for geography and urbanization. Generally, covariates behaved as we expected, with poor birth outcomes being associated with advanced maternal age, lower maternal educational attainment, unmarried status, and smoking status. Among non-Hispanic black rural births, maternal educational attainment, marital status, and smoking status were not significantly associated with pregnancy outcomes.

In models of binary outcomes among non-Hispanic white births, preterm birth and low birth weight were associated with season of conception in both statewide and urban county models ($P < .05$). Table 3 presents the covariate-adjusted odds ratios (aORs) and 95% confidence intervals (CIs) for the pairwise comparisons between seasons of conception, for all logistic models of pregnancy outcomes among non-Hispanic white births. Statewide, the odds of preterm birth were approximately 10% higher among spring conceptions and 6% higher among summer conceptions, compared with those for winter and fall conceptions ($P < .05$). Preterm birth followed a similar pattern among births in urban counties. In the statewide model, spring conceptions were more likely to be low birth weight than were conceptions in all other seasons ($P < .05$). Among births in urban counties, fall conceptions were less likely to be low birth weight than were spring and summer conceptions ($P < .05$), and winter conceptions were less likely to be low birth weight than were spring conceptions ($P < .05$). Small for gestational age was marginally associated with season of conception among non-Hispanic white births statewide, in urban counties, and in rural counties ($P = .05$, for all). Other than this marginal association with small for gestational age, no other binary pregnancy outcome was associated with season of conception among non-Hispanic white births in rural counties. Note that the smaller sample size in rural areas may account, in part, for nonsignificant statistical results.

Among non-Hispanic black births, only preterm birth was significantly associated with season of conception in statewide models ($P < .05$) (Table 4). The odds of preterm birth were higher among summer conceptions than among winter conceptions (aOR, 1.13; 95% CI, 1.05-1.21). No association between any of the binary pregnancy outcomes and season of conception was found in non-Hispanic-black–specific models when the analysis was restricted to births in rural or urban counties; thus, differences in the statewide model may be driven by differences in suburban counties.

Models that associated birth weight percentile for gestational age and season of conception are summarized in Table 5. Among non-Hispanic white births in rural counties, summer conceptions had a higher mean birth weight percentile for gestational age than did conceptions in all other seasons ($P < .05$). Among non-Hispanic black births across North Carolina, birth weight percentile for gestational age was also higher for summer conceptions than for fall or winter conceptions ($P < .05$).

TABLE 5.
Modeled Mean Birth Weight Percentile for Gestational Age, by Season of Conception, on the Basis of Race-Specific Statewide, Urban, and Rural Models

	Season of conception			
Race, area	Fall	Spring	Summer	Winter
Non-Hispanic white				
NC	46.60	46.32	46.90	46.57
Rural	44.62[a]	44.99[a]	47.06	45.07[a]
Urban	46.99	46.79	46.92	46.93
Non-Hispanic black				
NC	36.93[a]	37.16[a,b]	37.78[b]	36.84[a]
Rural	37.06	38.28	38.75	37.44
Urban	36.86	36.92	37.68	36.84

Note. Winter, December-February; spring, March-May; summer, June-August; fall, September-November. Models for each outcome were controlled for age, education, marital status, smoking during pregnancy, infant sex, and region of North Carolina (NC). Models for all NC counties also controlled for urban and rural county classification.
[a,b]In each row, if season of conception was a significant covariate in the model, on the basis of the type III P value, then sets of seasons with means that are not significantly different ($P \geq .05$) are noted with the same letter.

Discussion

Consistent with the findings of previous research, we found significant seasonal patterns in poor pregnancy outcomes. We conceive that seasonal patterns are a potential proxy for differing environmental exposures across seasons. Because of our access to the NCDBR, we were able to explore these seasonal patterns in greater depth. Our results suggest that, in North Carolina, seasonal patterns are most pronounced among non-Hispanic white women living in urban areas. This is somewhat surprising given the significantly higher rates of poor pregnancy outcomes among non-Hispanic black women in North Carolina and nationally. This seemingly anomalous result may arise from other, nonseasonal social and environmental factors overwhelming seasonal environmental exposures for non-Hispanic black women. These results are also surprising given the higher rates of poor pregnancy outcomes among women residing in rural areas in North Carolina and nationally. Again, this seemingly anomalous result may arise from other, nonspatial social and environmental factors overwhelming seasonal environmental exposures for women living in rural areas. In future work, we hope to disentangle some of these questions by implementing spatial models that go well beyond simply controlling for region of the state and degree of urbanization.

That we did not observe seasonal variation in maternal characteristics (except for rural births) differs from other analyses of seasonality and suggests that seasonal variation in birth outcomes is more likely caused by unmeasured environmental or other factors than by individual-level risk factors. This is confirmed in the adjusted models, where we controlled for individual-level risk factors and still observed significant seasonal patterns in poor pregnancy outcomes. We note that seasonality in the total number of pregnancies means that there is seasonal variation in the number of fetuses exposed to a given potential risk factor. This in itself could lead to seasonal variation in the attributable number of cases, even if the relative proportion does not change.

A limitation of the work in the present study is the reliance on data from the NCDBR, which includes only information on live births. We were thus not able to consider seasonal variability in early pregnancy loss; therefore, we may be understating the seasonal variation in pregnancy outcomes overall. The present study is further limited by the restricted set of maternal and pregnancy variables available from the NCDBR. A richer set of variables, potentially including psychosocial and activity measures, would allow us to more ably discern what is driving the observed seasonal patterns (although, note that such analyses would almost certainly be performed using substantially smaller sample sizes).

In the end, we do not consider season of conception, in and of itself, to be a causative factor for poor pregnancy outcomes. Rather, we believe it serves as a proxy for some other, time-varying factor. Thus, while we were able to discern seasonality, the present study is limited in its ability to identify the specific environmental or other factors that may be driving the seasonal patterns. The results do, however, suggest important directions for future research. In addition, the pronounced increased risk associated with a spring season of conception provides an important clue for ferreting out the true causative factors.

Conclusions

Poor pregnancy outcomes in North Carolina follow a clear seasonal pattern based on timing of conception. These seasonal patterns are most pronounced among non-Hispanic white women living in urban areas. These seasonal patterns are suggestive of causative environmental factors and certainly warrant additional research. In future research, we plan to explore potential environmental exposures as the drivers of the seasonal patterns demonstrated in the present study. NCMJ

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